AD-A236 515

DTIC

U.S. Naval War College

Newport RI 02841-5010

THE USE OF PRECISION GUIDANCE FOR WEAPONS:

Its Impact on the Operational Commander

by

Thomas J. KAPURCH

LCDR USNR

A paper submitted to the Faculty of the Naval War College in partial satisfaction for the requirements of the Department of Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

Signature:

21 June 1991

Paper Directed by COL Theodore L. Gatchel, USMC
Chairman Department of Operations
U.S. Naval War College

Approved by:

CDR Charles Marineau, USN
Staff Intelligence Officer
Operations Department
U.S. Naval War College

A-1

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No 0704-0188

1a REPORT SECURITY CLASSIFICATION UNCLASS	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY 2b DECLASSIFICATION / DOWNGRADING SCHEDULE	3 DISTRIBUTION / AVAILABILITY OF REPORT DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.
4 PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION Operations Dept 6b OFFICE SYMBOL (If applicable) C	7a NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) U.S. NAVAL WAR COLLEGE Newport, RI 02841-50±0	7b ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING / SPONSORING ORGANIZATION 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)

THE USE OF PRECISION GUIDANCE FOR WEAPONS: Its Impact on the Op Commander

12 PERSONAL AUTHOR(S)

LCDR Thomas J. KAPURCH, USNR

13a. TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
FINAL	FROM ______ TO ______	ii FEB 1991	66

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Precision guidance, smart weapons, ROE, Logistics, intelligence, commanders, limited war

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

High technology innovations have vastly improved precision guidance for weapons. Resultant capabilities expand operational commanders' flexibility while affecting, planning and command and control. Despite an ever increasing threat to manned aircraft, commanders are routinely restricted from fully using technology to its utmost. In light of recent events in the Persian Gulf, it would be beneficial to analyze the effects of precision guidance on intelligence, logistics and command and control. This report does in the low intensity/medium intensity conflict and ait-to-surface applications.

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION Unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL CHAIRMAN, OPERATIONS DEPARTMENT	22b TELEPHONE (Include Area Code) 401 841-3414 22c OFFICE SYMBOL C

DD Form 1473, JUN 86 Previous editions are obsolete SECURITY CLASSIFICATION OF THIS PAGE

S/N 0102-LF-014-6603

THE USE OF PRECISION GUIDANCE FOR WEAPONS:

Its Impact on the Operational Commander

High technology innovations in both aircraft and weapon system navigation, target acquisition and terminal guidance can provide extraordinary precision for air- and surface-launched weapon systems. Resultant capabilities provide war fighters with flexibility and an expanded capacity to strike a diverse target set in an environment of ever increasing sophisticated air defense (AD) systems. However, restrictions placed on the use of certain precision guidance technologies have had a serious impact on the operational commander. In light of recent events in the Persian Gulf, it would be appropriate to examine the issues affecting the use of weapon guidance systems. More specifically this report focuses on their use and operational-level impact with regard to:

* command and control, (C^2)
* logistics, and
* intelligence.

Review of these issues with regard to limited use of force in past, contemporary and future situations provides timely information for the operational commander who must deal with precision guidance capabilities and limitations.

PREFACE

It should be noted at the outset this report is not an all-inclusive analysis of precision guidance and the operational level of command. Rather, it is a focused study on the problems of command and control of air-to-surface and surface-to-surface operations in limited war. It should also be pointed out there is a rather extensive collection of data in Annexes I through IV. It is assumed the reader's knowledge of precision targeting systems and procedure is minimal. Therefore where relevant, references to the Annexes in which there is supporting data are made throughout the main text.

Due to the importance of joint operations, analysis of particular systems are not limited solely to a single service's weapons, systems and tactical operations. However given the size limitations imposed by the Operations Department syllabus and for purposes of further managing information in this article, data is limited. A representative list of weapon delivery cases is used; these are found in Annex III.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY

AA	Anti-Aircraft
ABL	Armored Box Launcher
A/C	Aircraft
AF	Airfield
BDA	Battle Damage Assessment
B/N	Bombardier Navigator
C^2	Command and Control
C^3I	Command, Control, Communications and Intelligence
CEP	Circular Error Probable (radius of a circular area within which at least 50 % fall of shot occurs)
EO	Electro-Optic (guidance or sensor)
DSMAC	Digital Scene-Mapping Area Correlator
FLIR	Forward Looking Infrared
FOSIF	Fleet Ocean Surveillance Intelligence Facility
GDIP	General Defense Intelligence Program
GP	General Purpose (bomb)
HARM	High Speed Anti-Radiation Missile (AGM-88)
INS	Inertial Navigation System
IR	Infrared
JSTARS	Joint Surveillance, Targeting and Recognition System
LOAL	Lock-on After Launch
LOBL	Lock-on Before Launch
LOS	Line of Sight
MAE	Mean Area of Effectiveness
MITL	Man-in-the-loop
MLRS	Multiple Launch Rocket System
MMW	State-of-the-art imaging radar technology
MOE	Measure of Effectiveness
NOIC	Navy Operational Intelligence Center
ONI	Office of Naval Intelligence
PCO	Peacetime Contingency Operation
PGM/PGW	Precision Guided Munitions/Precision Guided Weapons
PKO	Peace Keeping Operation
RCS	Radar Cross Section
RDB	Retarded Delivery Bomb
SEAD	Suppression of Enemy Air Defense
SLCM	Sea- (or submarine-) Launched Cruise Missile
SSK	Single Shot Kill
TERCOM	Terrain Contour Matching
TFW	Tactical Fighter Wing (USAF equivalent of USN VA, VF or VFA wing)
TLAM	Tomahawk Land Attack Missile
TLAM-C	Tomahawk Land Attack Missile (Conventional Warhead)
USAAF	U.S. Army Air Force (pre-1947 USAF organization)
VA	Attack Squadron Designation (A-6E/A-7E)
VF	Fighter Squadron Designation (F-14A/A+/D)
VFA	Fighter Attack Squadron Designation (F/A-18A/C)
VLS	Vertical Launch System (Mk 41 61-cell SLCM launcher)
WRM	War Reserve Munitions
WSO	Weapon System Operator (aircrew, similar to Navy B/N)

CHAPTER I

INTRODUCTION

Thesis. High-technology innovations in aircraft and weapon system navigation, target acquisition and terminal guidance afford an extraordinary capability for precise targeting. However, some innovations designed to solve targeting problems require less use of man-in-the-loop (MITL) interface after a weapon launch. Command and control is effected when MITL is replaced by system interfaces because a subsequent deficiency in human interaction results in greater uncertainty regarding mission planning.

Military commanders especially within the Navy are most likely to encounter war in the so-called "low- and medium-intensity conflict". Uncertainty, as well as the exorbitant cost associated with precision guidance weapons, are particularly important to the commander in a limited war for political reasons. This study, therefore presents an analysis of relevant limited warfare cases where operational commanders have dealt with issues dealing with use of precision cuing systems and weapons. It also provides information on the capabilities and limitations of contemporary and emerging precision guidance systems and how they have and will continue to influence contemporary and future command and control, intelligence and logistics.

The Environment. " Seldom if ever have (sic) the United States . . . been confronted with more profound international challenges than at present. [1] Our historic rival, the U.S.S.R, has seen its military and political influence decline as a result of

economic and political difficulties. However, numerous other crises now appear to threaten U.S. interests worldwide. Moreover, a coincidental increase of

> sophisticated weapons and delivery systems . . . (being) transferred to and/or developed by Third World states, increase(s) the risks and complicate(s) the battle management problem for U.S. forces and our allies. [2] [a] (Table 2.)

Analysis of OPERATION DESERT STORM clearly evinces both we and our allies are making extensive use of precision targeting to confront contemporary military challenges. As previously mentioned, certain precision guidance systems require less MITL interface. Increased reliance on intelligence and logistics support results from the expansion of closed-loop system functions required to offset the deficiency of MITL. It is appropriate at this time, therefore, when examining typical limited warfare cases to determine the support impact various MITL and closed loop systems have on the operational commander.

A Paradigm For Precision Guidance and Force Projection. The following nine weapon hardware examples or launch situations are typical of those that are either presently being used or are in engineering development and expected in the field in the foreseeable future. These examples can be used to examine different types of precision guidance and the effect the operational commander. (See also, Annex III.)

[a] The idea that the Navy faces a high probability it will encounter low and medium intensity conflict is not new. "Throughout the post . . . (WWII) period, the United States has turned most often to the Navy when it has . . . employ(ed) components of the armed forces (over 215 times) in support of (limited) political objectives." [3] The Navy officially embraced the concept of use of force along a "level of intensity curve" (Figure 1.) in the mid 1980's, when the Maritime Strategy was first submitted by (then CNO) ADM Watkins. The events in Europe in 1989 and in the Middle East in 1990 and 1991 only serve to support the logic of the concept. [4]

Case	launcher	weapon	target acquisition/ terminal lineup	guidance after weapon launch
1	aircraft	GP Bomb	MITL	none
2	aircraft	GP Bomb	Launch on Coordinates	none
3	aircraft	PVWY II LGB	MITL/LOBL Radar/INS/GPS Cued	command laser
4	aircraft	PVWY III LLLGB/ PVWY II LGB	MITL/LOAL	ground or command laser
5	aircraft	GBU-15/AGM-130	Launch on Coordinates	command TV
6	aircraft	GBU-15/AGM-130 SLAM/PVWY III + [b]	Launch on Coordinates LOAL	Autonomous IIR, mmw
7	aircraft	Standoff Land Attack Missile (SLAM)	LOAL/LOBL	command TV/ GPS aided
8	surface, sub or aircraft [c]	TLAM - C	Launch to Coordinates Positional NAV only	Autonomous TERCOM
9	surface, sub or aircraft [c]	TLAM - C+ [b]	LOAL	Autonomous IIR, mmw

In order to achieve a high single shot kill (SSK) probability, conventional weapons require a fairly accurate targeting solution. As a rule of thumb, total error required for hard point targets is less than 10 feet, for soft point targets less than 100 feet. (Figure 2.) Certain terminally guided or navigation aided only weapons, once launched, must achieve targeting requirements with limited or no Man-in-the-Loop (MITL) interface. One consequence is for example, that with a non-MITL terminally cued weapon system's (such as a cruise missile's) potential for high probability of SSK due to precise circular error probable (CEP) can be mitigated due to its low tolerance for target location error (TLE). [d] Therefore, a complex weapon system capability can be rendered over-

[b] There are USAF-sponsored technology programs now underway to develop a weapon guidance system that would be similar to Walleye and GBU-15, but preclude the need for a data link. With such a system, aircrews would "prebrief the seeker with enough information about the imagery of a target to enable seekers" [7] to actually autonomously "look" for a specific target. Key to the program would be the target mission prebriefing system that would program a missile onboard computer which would govern the acquisition process. USAF Tactical Air Force Command is considering such as system for the AGM-130 and Paveway (III bomb kit; Strategic Air Command would like to create such as system for conventional munitions for air-launch cruise missiles. [8]

[c] Due to strategic weapon limitations, TLAM is not currently deployed on Navy tactical aircraft. However, TLAM launches were performed from fleet aircraft and TLAM could be deployed with minor modifications to the A-6E.

ly susceptible to strict operational planning constraints outside the boundary of the weapon system itself, in this case intelligence agency availability or its capability to determine a very precise target location.

Over reliance on a support system or susceptibility to operational limitations can render precision guidance systems inflexible as the probability of single shot kill (Pr_{ssk}) becomes more a function of capabilities in a close-loop mechanical system. The inherent limitations in such situations are especially critical considering rules of engagement (ROE), logistics and intelligence requirements have mitigated the advantages of precision guidance.

Naval Aviation. In comparison to sophisticated guidance weapons, Naval Aviation in certain situations, permits the use of less complex MITL cuing, and are therefore is relied on heavily in contemporary limited warfare planning. (Table 1). Naval Aviation "tactics and weapon loads can be tailored to the specific mission and most importantly--air crewmen can react to the unexpected." [5] In one sense, the use of manned aircraft allows the commander to delegate final command authority to a decision maker close to the scene of weapon impact. Such a capability provides inherent redundancy to ensure adherence to key targeting requirements:

* correct detection, identification and acquisition;
* precise terminal guidance;

[d] Total error for non-LOS, terminally guided and/or passive lock-on after launch (LOAL) weapons have essentially two sides: target location error (TLE) is a relative or absolute location based on an intelligence estimate or pilot navigation error at launch. CEP of the system is based on weapon systems ac-curacy. Total targeting error is the root of the sum of the squares of TLE and CEP. In order for terminally guided munitions to be effective, TLE can be no greater than an elliptical area prescribed by the system's Field of View limits and altitude and attitude at the time the guidance system initializes target search and acquisition. In order for a navigation only system (i.e. TLAM) to be effective TLE can be no greater than the approximate radius of the warhead's Mean Area of Effectiveness (MAE.)

* proper weapon aimpoint and warhead dive angle; and

* a sustainable means of delivery against a wide variety of target types, sizes and resilience.

Comparisons. "Modern technology in the sophisticated weapons that U.S. forces are facing on Third World Battlefields rivals or equals weapon technology fielded by the Soviet Union." [6] (See also Table 2.) Given the threat, it would be prudent for operational planners to become better informed of the issues concerning the use of precision guidance, if for nothing more than the improved stand-off precision weapons allow. An analysis of the nine weapon launch cases (Annex III) used in this report is a study of precision guidance and command and control that spans the two extremes that manned aircraft and cruise missiles characterize: operational flexibility on the one hand, launcher survivability on the other.

CHAPTER II

COMMAND AND CONTROL AND PRECISION GUIDANCE: PAST AND PRESENT

Background. During a period spanning 34 years, from the beginning of American involvement in World War II to our withdrawal from Vietnam, technological innovations have resulted in an exponential leap in the capability to guide air-launched weapons to an intended target. For example, on 29 May 1943, the U.S. Army Air Force (USAAF) recorded its most effective raid of the Battle of the Ruhr. That day, approximately, "450 (70 %) of the 657 aircraft (flown) dropped their bombs within three miles of the aiming point and the damage covered over 1,000 acres. Total loss of production from (this day's raid on) the Ruhr was less than 10 percent." [9]

Nearly 29 years later, on 10 May 1972, sixteen F-4Ds in four flights, configured with laser- and electro-optic (EO) guided glide bombs, struck the Paul Doumer bridge near Hanoi. These aircraft made 12 direct hits (77 % of the bombs dropped) within an estimated CEP of ten feet of aimpoint. Battle Damage Assessment (BDA) indicated at least one span was dropped and the target became completely inoperative (a "K-Kill"). Although the area was heavily defended by SA-2 Surface-to-air Missiles (SAMs--over 160 were fired) the USAF lost no aircraft. [10]

The first combat use of precision guided weapons (PGWs), increased mission effectiveness due to their extremely small circular error probable (CEP) and very high single shot kill SSK probability. "Television-guided and laser-guided bombs could do the job of at least 10 times the number of unguided bombs, meaning fewer aircraft had to be exposed to the extensive North Vietnamese an-

tiaircraft defenses." [11]

Capability vs. Operational Constraints. With the capacity precision guidance afforded in Vietnam, operational ROE appeared to be less of a factor since commanders could plan fewer aircraft be used and target restrictions eased, especially interdiction sets near built up areas. Therefore, when considering the technical and operational improvement in precision guidance that began in Vietnam and continued throughout the next 20 years, it would appear at first inspection, precision guidance would afford nothing less than an extraordinary military advantage for the modern operational commander.

However, it should be remembered that during the same war in which we were able to score with such stunning proficiency as in the attack on the Doumer Bridge, American commanders were faced with "crippling restrictions on (the use of) air forces." [12] Furthermore, Vietnam would serve as a paradigm for things to come, as future operational commanders would later have to restrict full use of technological advantages that breakthroughs in precision targeting were to provide.

For example, more than 20 years after Vietnam, VADM Metcalf, commander of Operation Urgent Fury, the 1983 Grenada Rescue Operation, opined that Rules of Engagement (ROEs) placed on him with regard to the use of firepower "presented the toughest challenge to the accomplishment of the mission. . . . (He therefore) decided that if he was (sic) to ensure minimum damage to both sides, then (he) had to (closely) control the release of highly destructive weapons." [13]

Implications For The Present. A concurrent growth in other problems affecting command and control is also being exacerbated by increased demands made on command systems. Technological developments have multiplied the disposal of command systems, but changes in command process and advances in weapons have increased costs. [14] According to the Air Force Chief of Staff "all aspects of C^3I will be more critical as the USAF gets smaller and has somewhat less forward basing. For surveillance in strategic and tactical settings, the Air Force will rely more and more on satellites, and on unmanned aircraft." The ability to use these and other systems such as JSTARS and AWACS will be challenged by priorities for strategic arms control verification and even scheduled drug-interdiction. [15]

In light of support constraints and political and operational limitations likely to occur with limited warfare, technical capability may be offset by either self-imposed operational restrictions or logistics constraints. Among other concerns a commander may very likely be faced with extraordinary circumstances regarding limited war operations, such as:

* imposition of special operational restrictions to weapon employment, which may compromise effectiveness;
* regard for logistics constraints in an era of increased fiscal budget concerns; and
* despite a requirement for greater reliance on intelligence assets, a competition for their support.

Special Operational Limitations. As mentioned, technology and improved tactics provide an incredible military advantage when using air- and sea-launched precision weapons, but other non-militarily expedient issues can force a compromise between political expediency and optimal performance.

The use of precision guidance for weapons in Vietnam "was a key element contributing to the success of the U.S. interdiction effort in 1972. With a 'smart' precision guided weapon, the probability of hitting the target was estimated to be an unprecedented 80 to 90 percent." [16] However, due to the President's "fear of incurring adverse world opinion. . . detailed instructions as to targeting . . . were extended to include the fusing of bombs, time on target (TOT), ordnance load and even, on occasion, the direction of attack. Built up areas were to be avoided at all costs, providing sanctuaries in which the North Vietnamese could build stores and their AA defenses." [17] As previously, mentioned the imposition of operational restrictions did not end in Vietnam as EL DORADO CANYON serves as a more recent example.

In 1986, when President Reagan decided EL DORADO CANYON would be executed, he directed U.S. forces attack terrorist-related activities in Libya while ensuring that "no other economic or military targets" were threatened. (T)he "Crisis Pre-Planning Group . . . formulated a series of military options . . . (that) included bombing raids by (N)avy jets, F-111Fs based in Britain, or even devastating American-based B-52G and B-52H Stratofortresses. Proposals (also) included pinpoint strikes by BGM-109C Tomahawk . . . cruise missiles." [18]

Command decisions made during both the planning for and execution of EL DORADO CANYON epitomize the importance afforded to special operating limitations and their impact on the use of precision guidance for weapons. Final direction placed operational limits on the full use of precision guidance capacity for other than strictly military expediency. In effect, a trade off resulted when the concern for technology compromise, ROE and collateral damage was prioritized over optimum capacity to use unrestrained precision guidance to ensure maximum survivability.

Technology Compromise. An adequate number of unmanned cruise missiles launched from B-52Gs or from warships could have been used to strike Libya with precision, affording both sufficient mission effectiveness and precluding any need to penetrate Air Defenses (AD) with manned aircraft. However, B-52 and cruise missile options were ruled out "because there was no desire to compromise these technologies when other devices could do the job." [19] •

ROE and Friendly Survivability--Operational Planning. Even after a decision to use manned aircraft was made, military leaders still feared ROEs placed on aircrews, would have permitted "vigorous repercussions by (a) largely untouched Libyan military (since) Reagan (had) steered (them) to a thorough consideration to force open clear paths to get at terrorist-related targets . . . and no others." [20] Despite the concerns of a higher risk to aircraft survivability posed by strict adherence to the original manned aircraft ROE, political pressure prevailed and military

• A concession of sorts, with respect to other types of technology compromise, however, was eventually reached despite such aprehensions. The desire to strike with "surgical" precision weapons (Table 3.) outweighed a risk of compromise of these systems. (High Speed Anti-Radiation Missiles (HARMs) and Paveway II Laser Guided Bombs (LGBs), used in this raid are themselves, high technology systems.)

commanders developed their plans and choice of targets for Suppression of Enemy Air Defense (SEAD) accordingly.

ROE and Friendly Survivability--The Execution. The importance that operational commanders in EL DORADO CANYON placed on limitations to optimal use of precision guidance for other than military reasons, becomes even more apparent when one examines the execution phase of the raid itself. "Six Air Force bombers out of eighteen (33 percent) and three Navy jets of fifteen (20 percent) . . . failed to engage their aiming points." [21] The fact that so many aircraft aborted did not indicate total system failure as some critics have charged. Rather, it demonstrated the significance placed on the use of maximum redundancy and optimal MITL interface despite the capabilities of targeting systems to do otherwise. The decision to abort in all cases was based on orders that precluded aircrews from using "less accurate backup methods" such as launch on coordinates even though they were available. [22]

For further analysis of this operational decision, consider a paradigm of the launch options compatible with the weapons and aircraft available for EL DORADO CANYON--Annex III and page 3:

Case	weapon	target acquisition/ terminal lineup	guidance
1	GP Bomb	MITL	none
2	" "	Launch on Coordinates [f]	none
3	PVWY II LGB	MITL/LOABL Rada/INS/GPS Cued	command laser
4	PVWY III LLLGB *	MITL/LOAL Launch on Coordinates [f]	command laser
5	GBU-15	MITL/LOAL Launch on Coordinates	command TV

8	TLAM-C	Launch to coordinates Positional NAV only	Autonomous TERCOM

* Although PVWY II can be used in a pop-up mode to launch on coorordinates, PVWY III with its 30 ° Field of View is the optimum choice for a LOAL targeting option. (Full scale production of PVWY III was canceled in the mid 1980's.)

Cases 1 and 3 were the only ones executed. Cruise missiles were rejected outright (Case 8) and GBU-15 (Case 5) was not selected. (Considering ROE, it is unlikely GBU-15's optimum [g] mode of launch on coordinates would have been exploited due to concern for possible failure to lock-on after launch and implications for collateral damage.)

CASES 1-4. When using either general purpose (GP) or Laser Guided Bombs (LGB) a launch on coordinates (without target acquisition PRIOR TO LAUNCH) yields a solution that is not as accurate or as reliable as a launch on visual or sensor (i.e. Forward Looking Infrared [FLIR] aircrew-to-target LOS) cue. However, it does afford additional safety with respect to terminal air defenses, in that aircraft can avoid flight over or near a defended target area for an extended period of time.

Footage of PAVE TACK (IR/Laser sensor and tracking pod) cameras suggests, ROE requiring target acquisition prior to launch to ensure innocent civilian lives were protected as much as possible, was in fact strictly followed. [23] In this situation, preconditions

[f] A GP launch on coordinates uses aircraft/aircrew navigation to arrive at a predetermined point, and a "blind launch" (non-LOS cued) based on aircraft navigation system and flight computer estimates that determine heading, attitude, altitude and location at launch. As such it is reliant on target data input based on intelligence sources, prebriefed prior to aircraft launch. As such CEP and TLE error has a lesser probability of success than an LOS-aided solution. An LGB launch on coordinates is similar, but to be effective requires a post launch pop-up maneuver and target designation, again based on estimates derived from pre-launch intelligence data bases.

[g] This is assuming of course, one considers optimum as the mode that allows for optimum aircrew safety and survivability in a defended target area.

of cases one and three were met. The analysis suggests that during EL DORADO CANYON, commanders prioritized accuracy and concern for collateral damage, despite the availability of more optimal uses of precision guidance and over assurances to ensure aircrew survivability.

Logistics Procurement. In 1985, Congressman Denny Smith of Oregon warned, because of the emphasis placed on "procurement of glamorous, sophisticated and expensive weapons systems" level of War Reserve Munitions (WRM) would suffer. He feared such neglect would lead to a failure to "establish a proper level of war reserves" and in turn, inadequacy to sustain combat beyond "a few days. (In 1985, WRM was estimated at less than 30 days.)" [24] Rather than take issue with a subject that is well beyond the scope of this report, consider at least the following.

The Gulf War notwithstanding, all indicators suggest defense spending in the 1990's will not receive the priority it has in the last decade. Suffice it also to say, despite reasoned arguments that support robust procurement of precision guidance weapons and systems, extensive use in DESERT STORM being one, cost and budget priorities will most likely take precedence over reasoned arguments. This will cause a less than optimum supply of precision weapons available to operational commanders. Furthermore consider an excerpt (next page) from Table 3 (Annex II):

Although operational decision-making does not directly affect procurement directly which is a key strategic planning issue, it is important for operational commanders in Peacetime Contingency (PCO) or Peace Keeping Operations (PKO) to have a general knowledge of

of current production capacity.

Weapon	Approx Cost ($ 000's)	Approx Annual Procurement Rate
GP Bombs	2-4	500,000
PAVEWAY LGBs	5-6 *	156,000
PAVEWAY LLLGBs	45-66 *	120,000
Walleye	---	550
SLAM	--- **	360 **
TLAM-C	1,347	400-600
AGM-130	610	30-40 ***

* PVWY II/III is not in full scale production. These figures reflect what total capacity was before termination of PVWY II and cancellation of PVWY III in the early 80's.

** SLAM is still a developmental effort. Those being used in the Persian Gulf are pre-development rounds. Over three hundred were requested by the Navy before Desert Storm. Procurement is still uncertain.

*** AGM-130 development is similar to SLAM in that final procurement has yet to be decided.

It may be argued that during general, unlimited war scenarios, history has shown that America's surge capacity to meet wartime needs is one of its overwhelming strengths. During PCO/PKO operations, however, planning will be constrained by the existing war material manufacturing base. A general knowledge of this base would therefore be helpful to the operational commander in the planning process. Using the excerpt from page three consider the following relationships:

* one year's production rate of Walleye was approximately equal to the number of attack airplanes (F-18, A-7 and A-6) in the thirteen air wings of the U.S. Navy, SLAM's is even less;
* Paveway II/III bomb kits are not in full scale production; these are the only guided systems that have been bought in quantities typical of guided bombs;

* one year's procurement of all TLAM system variants are not enough to provide three per the ships that have launcher capacity (includes those planned [i.e. SSN-21, DDG-51]).

Considering the fiscal climate of the 1990's in addition to all of the above, suffice it to say, an operational commander must keep strategic logistics constraints in mind when planning PCO/PKO missions. Given the constraints of peacetime budget priorities, even if a technology or product exists, and aircrews and ship and submarine crews are properly trained with them, it is likely supplies of sophisticated hardware at the outset of hostilities may be inadequate for sustained operations.

Combat Supply of Weapons. RADM Eccles opined "since logistics flexibility is the primary physical base of strategic flexibility, the command control structure must include adequate means for the integration of critical logistic considerations throughout its entire structure and operation." [25] As the previous section illustrates certain cost and availability numbers create a concern that should not be overlooked by operational commanders. Furthermore, inherent complexity and highly specialized functions typical of precision weapon systems exacerbate operational flexibility, with respect to sustainment once forces are committed. Nowhere are these issues of more concern than with the use of the Sea-Launched Cruise Missile (SLCM), BGM-109 TOMAHAWK (Annex IV.)

On the one hand the missile exhibits versatility and adaptability due to its flexible launcher applications (Annex IV). On the other, it manifests characteristics that require judicious uses in combat. TOMAHAWK is a very costly weapon, over one million dol-

lars per round. When deployed from surface or subsurface warships, not only are there no missile reloads available, replacement rounds must be loaded pierside. Finally, when used with the vertical launch system (VLS) either the number and/or type of TLAMs, Standard ARM or HARPOON (submarine only) must be adjusted. This condition results in an inherent magazine constraint that forces limitations on the platform's Anti-Air Warfare (AAW), Anti-Surface Warfare (ASUW), Strike Warfare or nuclear deterrence missions. [h]

Since "shipboard inventories of such weapons (are so) limited, (by comparison) in a single strike a carrier air wing could deliver more firepower than three or four Spruance class destroyers, while retaining enough weapons for additional strikes." [27] It is apparent when contemplating the operational advantages of ordering a cruise missile or coordinated aircraft and cruise missile strike, sustained operations capability of deployed surface ships and submarines is a key issue. [i]

Intelligence. For those familiar with Naval Intelligence, it comes as no surprise the community has kept a clear focus on strategic deterrence and global war fighting issues. Although in the 1980's the Office of Naval Intelligence (ONI)

> was able to respond to real world U.S. military operations . . . (its) response was almost always an ad hoc nature: pulling a few officers out of X division and putting them into Y division . . . Because of the heavy concentration on the Soviet problem, there was never a permanent, top down architecture developed to meet non-Soviet mission areas. [28]

[h] "U.S. strategic offensive forces consist of a triad of capabilities: long-range strategic aircraft, land-based intercontinental ballistic missiles (ICBMs) and submarine launched-ballistic missiles and cruise missiles [SLCMs] (sic). [26]

[i] In the last week of January, it was reported that over 240 "conventionally armed BGM-109C cruise missiles have been fired in the war." [29] (This is about 60 % of TLAM's one year total production [all variants] and in terms of weapon round costs alone represents 38 % of one day's total defense budget!)

Certain systems now being used, among other things, have "a tremendous appetite for data bases (which results in) an increasingly important role" [29] for intelligence support. Compared with Vietnam era PGWs, cruise missiles and closed-loop, standoff weapon systems pose additional operational uncertainties. A "cruise missile is no more than a small aircraft . . . susceptible . . . to the same type of attack (and targeting error) as (a manned) aircraft." [30] However, unlike the latter, many decisions affecting a cruise missile's aimpoint and final impact point must be made before launch.

The more recent examples of the use of precision guidance, EL DORADO CANYON and the manned aircraft interdiction missions of DESERT STORM, have two important command and control elements in common. 1) Both rely on MITL interface in the vicinity of the target, either with data link (SLAM) or MITL command laser guidance (Paveway II and III). 2) The level of air defense threat in both these situations does not compare to that anticipated for conditions that will warrant the use of a medium range standoff or cruise missiles in a so-called "high threat environment."

As the data in Annex III and Tables 5 and 6 suggest, the further back in the launch sequence MITL interface is precluded, the greater the need for tailored intelligence. Almost all of this information is acquired through some form of overhead imagery and intelligence support facilities serving the fleet "are heavily focused on the Soviet Union, particularly in the field of imagery exploitation." [31] Therefore it is important that operational commanders realize while intelligence agencies support to limited warfare

operations with tailored products will not be impossible, it will require surge operations on the part these agencies at a time when "across the board spending cuts are . . . forecast by the services and the General Defense Intelligence Program (GDIP). [32]

CHAPTER III

OPERATIONAL COMMAND AND CONTROL (C^2): THE FUTURE

Background. An initial analysis of air-to-ground operations in DESERT STORM suggests that, in actuality, operational command and control of the use of precision guidance has changed little since the Vietnam era, when the so-called "smart" weapon was first introduced. Hardware and software improvements in various systems such as the Paveway series, GBU-15 and AGM-130 and Walleye and the introduction of SLAM have provided at least the following:

* extended launch envelopes, allowing more tolerance for navigation and aircraft attitude errors;
* allowance for the use of launch on coordinates and lock-on after launch tactics; and
* improved weapon standoff range.

Various systems such as GPS are entering the fleet today and are providing even more capability such as a vastly improved GP bomb launch on coordinates capability. (See Annex IV [GPS].) However, during two of the most important limited war engagements since Vietnam, EL DORADO CANYON and DESERT STORM, and mostly due to ROE that still required MITL interface, there has been little indication that operational commanders have been willing or able to allow these innovations to be completely exploited.

Implications For the Future. Today industry appears to be at or near another breakthrough in precision guidance, one that may take us from "smart" to "brilliant" weapons. For example, some of the Advanced Medium-Range Air-to-Air Missile's (AMRAAM) reliability problems that led to its previous suspension have been addressed.

AMRAAM is a beyond-visual range missile. The USAF is restructuring TACIT RAINBOW which is designed to provide a loitering anti-radiation system that autonomously launches a warhead when cued by radio, radar or jamming emissions. [33] The USAF Systems Command is experimenting with an improved seeker for its GBU-15 and AGM-130 glide and boosted glide bombs. It would allow lock on without MITL after launch on non-cooperative (non-emitting) targets. [34] Finally the Army is analyzing a terminally guided projectile for its Multiple Rocket Launch System (MLRS) which would lock on autonomously to passive targets. [35]

Considering what has been observed in EL DORADO CANYON and DESERT STORM with regard to ROE and the requirement for MITL target acquisition before weapon launch, it might be appropriate to ask a rhetorical question before venturing further. That is, are there any limited warfare scenarios envisioned today, where consequences for national security are of such importance, both strategic and operational commanders can plan for either the full use of today's systems or even limited use of the "brilliant" systems on the threshold of production?

It would not be difficult to speculate as to the worth of brilliant weapon systems in a global conflict with the Soviet Union. Suffice it to say, in a war as big as one in which the widespread use of nuclear weapons could be contemplated, ROE and concerns for shrines or economic infrastructure and concern for individual weapon cost, pale in comparison to the importance they enjoy now or have in the past. Therefore, the design of and operational doctrine and training for new cutting-edge systems, may not

place ROE for limited warfare high on the list of priority concerns.

There appear to be few cases in the past that lend assurance to operational commanders they can expect to have full use of technology's capabilities in limited wars. Limited use of force, is the type of conflict in which U.S. forces are most likely to participate in, but design of and training for precision guidance use appear to be mainly focused on global conflict.

Intelligence. There have already been examples where demands for intelligence support to low intensity conflict has created a sort of competition. Since the end of World War II there has been a heavy focus on issues concerning strategic deterrence and global war fighting. But there have been limited successes with regard to support to limited war operations:

> Despite ONI's continued Soviet focus, intelligence support to meet non-Soviet requirements grew rapidly in the 1980s. NOIC (Navy Operational Intelligence Center) World Navies Department, for example, was expanded to monitor the growing capabilities of Third World navies like those of Libya, Syria and Vietnam. FOSIF (Fleet Ocean Surveillance Intelligence Facility) Rota provided intelligence support to forces involved in hostilities against Libya in 1986. [36]

However, when deriving conclusions based on intelligence support and lessons learned, it is important to note one of the major differences that has set today's Gulf War apart from EL DORADO CANYON and URGENT FURY.

One thing DESERT SHIELD/DESERT STORM has afforded the U.S. intelligence community is the luxury of time. Iraqi forces invaded in August 1990 and the U.N. coalition initiated retaliatory measures in January 1991. In September of 1990, Aviation Week reported

"image processing technicians and photo analysts . . . ha(d) been working 18 hours a day to maintain a steady flow of intelligence data to the National Command Authority and the U.S. forces in Saudi Arabia" [37] Accepting Aviation Week's report that Intelligence collection agencies are on a war footing for support to Gulf Operations, [38] the following is submitted.

The intelligence community's actions since August were key to successes enjoyed by the U.N coalition so far in the Gulf War; initial reports of TOMAHAWK's success support this. However, Aviation Week reported that surge operations had begun in September. This suggests the intelligence "surge" support cycle was initiated at least four and one-half months before commencement of hostilities. The planning cycles for URGENT FURY and EL DORADO CANYON were approximately three to four days. Quite obviously, these operations did not receive the level of support today's operations have, due to the time factor alone. Therefore, with regard to planning for possible future, limited war scenarios it is important that operational commanders keep things in perspective. Service component intelligence is still focused on the global threat. While some intelligence agencies possess a versatile architecture to allow for non-Soviet support, "long term intelligence support to Low Intensity Conflict is . . . a second priority." [38] Unless there are major changes in architecture, this will remain the case.

Refer to the supporting data in Tables 4 and 5; each are representative of intelligence related data for "smart" and "brilliant" weapons respectively. Although target location errors do not differ appreciably with respect to error tolerance, notice one

important element in Table 5.

In addition to absolute target location errors on the order of 1,000 feet, a brilliant system requires very specific data (on the order of less than 5 to 20 percent absolute dimensional error) with respect to individual target structures. In other words, support to the use of emerging technology systems in limited wars may require much more than a regional shift in intelligence targeting. It may also be necessary that target intelligence folders include a very detailed analysis of specific target area elements that a close-looped system can be programmed to acquire after launch. Considering the time constraints placed on commanders in operations such as URGENT FURY and EL DORADO CANYON, given the history of stringent ROE used in these operations and considering the Soviet focus the intelligence command now has, support for brilliant munitions requires a fair amount of forethought on the part of the commander's estimate of capabilities.

In a statement before Congress, Director of Naval Intelligence, RADM Brooks, displayed his appreciation for modern weapon systems' requirements by saying he realized they had a large "appetite" for data bases. It is safe to assume the intelligence community is aware of the unique responsibilities it has to support the operational commanders in their use of precision guidance systems. However, as it is with other services and components of the Navy, current budget constraints and the changing world order are presenting new competitive challenges to the execution of these responsibilities.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

<u>Summary.</u> With the exception of TLAM strikes during OPERATION DESERT STORM, the vast majority of real world precision guidance options used in weapon strikes by U.S. forces have relied on proven system concepts and ROE that date back to the Vietnam War. It should be remembered the precision guidance of choice in recent activity has been characteristic of Case 1 and 3 (Annex III). Obviously, most of the operational limitations so far have centered around stringent requirements to ensure MITL provides the highest likelihood collateral damage is kept to a minimum.

Budget constraints in the near and medium term will continue to force limitations in procurement and may result in less than an optimum number of sophisticated weapons, already considered by some to be inadequate. At the same time, intelligence agencies needed to support precision weaponeering, although not expected to be as restrained when compared to weapon procurement budgets, will nonetheless be effected by fiscal limitations.

<u>Conclusion and Recommendations.</u> With recent emphasis placed on the level of intensity curve, it has been suggested operational commanders, when required, should prepare to adapt weapons and systems designed for global warfare to meet the needs of limited war. Perhaps it is time to reverse the philosophy.

That is, all of our experiences with armed conflict since World War II have been of a limited nature. As EL DORADO CANYON and DESERT STORM illustrate, however, for those involved in combat, the term "limited" is academic. The aircrews are being tasked to

face the kinds of intense Air Defense environment that RADM Brooks and others have warned is being proliferated in the Third World. We are now faced with the dreadful specter of American Prisoners of War being held by an enemy who disdains the rules of war just as much as the U.S. adheres to them.

For a large part, these aircrews are being constrained by ROE that have not changed in principle since Vietnam and perhaps they should not be. However, it is time operational commanders:

1) prioritize training and war fighting career progression paths to match the demands of limited warfare;

2) become more familiar not only with the intelligence analysis process, but with those elements of that process that must be used to support smart weapon upgrades and brilliant weapon's debut into the military arsenals;

3) become more familiar with other service surveillance, command, control, communication and intelligence (C^3I) and logistics structures and hardware, and;

4) become more involved while still in the operational environment, in the new weapon and system design cycle--taking the initiative to learn and critique new systems and designs while they are still in the design phase.

ANNEX I

FIGURES

THE LEVEL OF INTENSITY CURVE

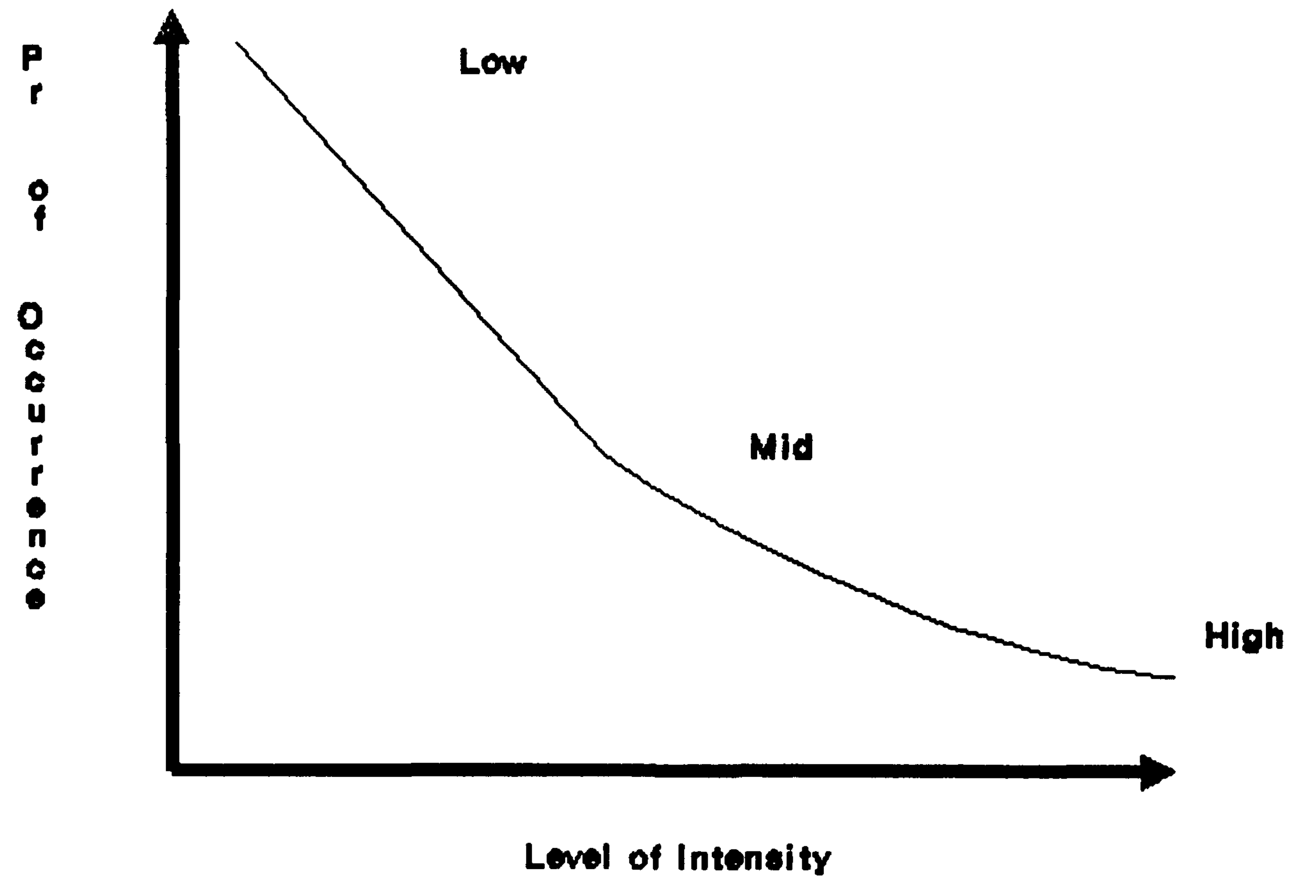
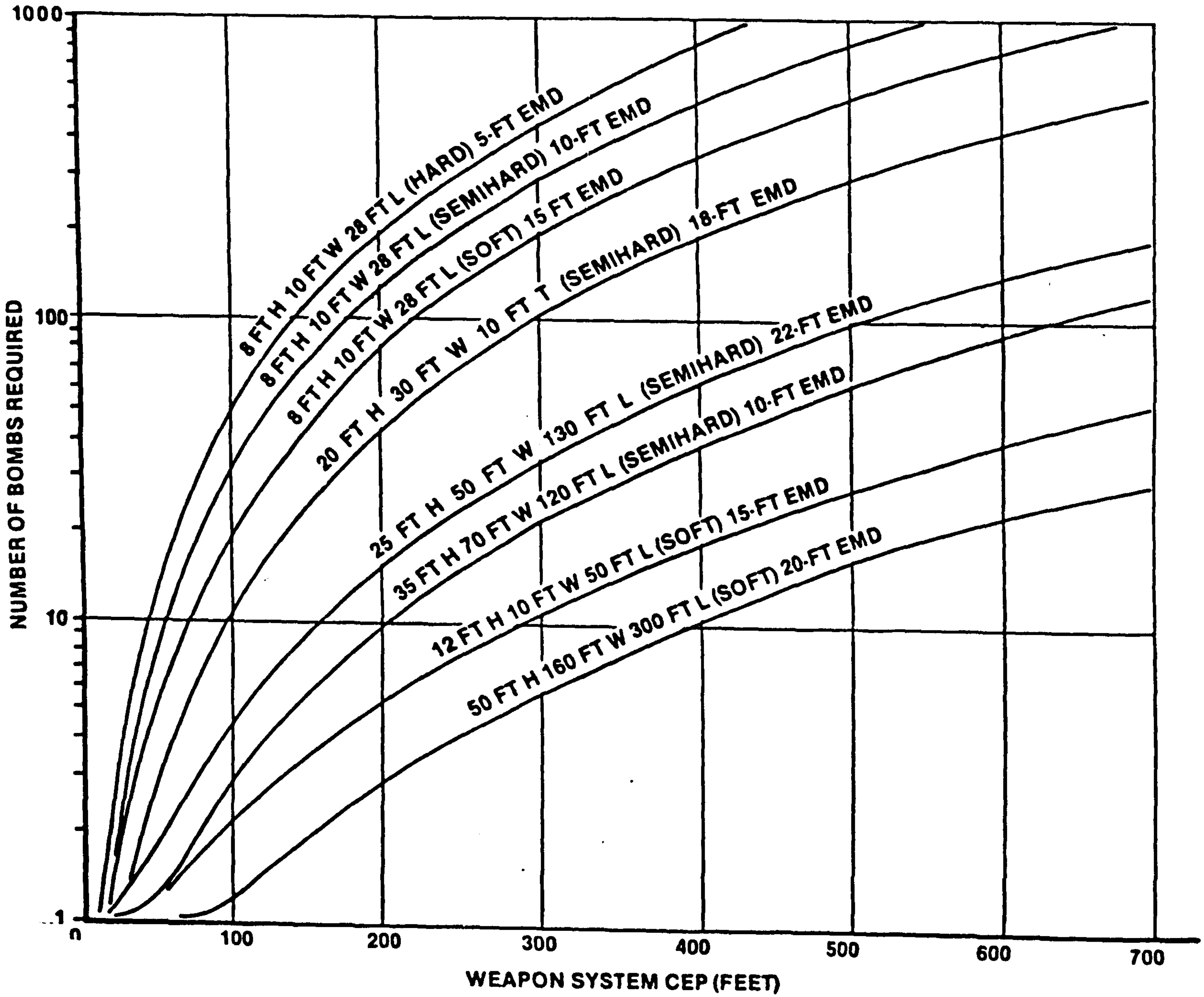
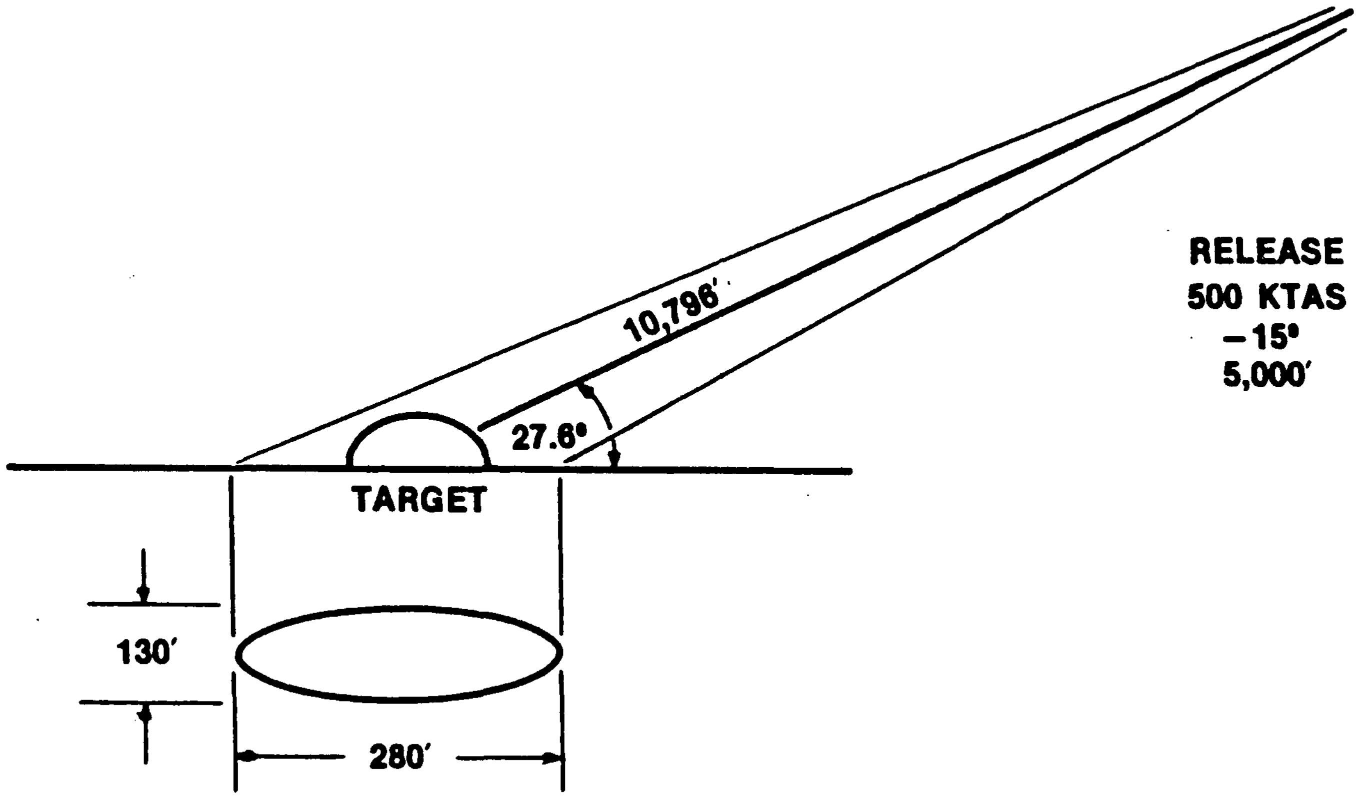


Figure 1.



NUMBER OF BOMBS REQUIRED
1000
100
10
1
0
100
200
300
400
500
600
700
WEAPON SYSTEM CEP (FEET)
8 FT H 10 FT W 28 FT L (HARD) 5-FT EMD
8 FT H 10 FT W 28 FT L (SEMIHARD) 10-FT EMD
8 FT H 10 FT W 28 FT L (SOFT) 15 FT EMD
20 FT H 30 FT W 10 FT T (SEMIHARD) 18-FT EMD
25 FT H 50 FT W 130 FT L (SEMIHARD) 22-FT EMD
35 FT H 70 FT W 120 FT L (SEMIHARD) 10-FT EMD
12 FT H 10 FT W 50 FT L (SOFT) 15-FT EMD
50 FT H 160 FT W 300 FT L (SOFT) 20-FT EMD

COMPUTER RELEASE
(12 MIL ACCURACY)



CEP 358′

NOT TO SCALE

ANNEX II

TABLES

Type	Approximate Procurement Rate 1,000s/yr	Approx Unit Cost $ 1,000	Approx Launch Range(NM)	Optimal CEP (ft)	Guidance	Target Types	Launcher
Unguided							
GP Bombs	500	2-4	3-5	100	None	All	F/A Aircraft
'Smart' Navy							
PAVEWAY LGBs	156 [1]	5-6	2-3	< 10	Laser/Command	All	F/A Aircraft
PAVEWAY LLLGBs	120 [2]	45-66	3-4	< 10	Laser/Command	All	F/A Aircraft
Walleye	550 [3]	---	16-35	< 10	TV/Command	All	F/A Aircraft
SLAM	.3 [4]	---	50 +	< 10	TV/Command	All	F/A Aircraft
TLAM-C	.4-.6	1,347	700	< 100	INS/DSMAC Autnomous Nav	All	Surface and Subs
'Smart' USAF							
PAVEWAY LGBs	156 [1]	5-6	2-3	< 10	Laser/Command	All	TFW Aircraft
PAVEWAY LLLGBs	120 [2]	45-66	3-4	< 10	Laser/Command	All	TFW Aircraft
GBU-15	30-60 [5]	100 +	3-5	< 10	TV/Command	All	TFW Aircraft
AGM-130	30-60 [6]	610 +	25?	< 10	TV/Command	All	TFW Aircraft
"Brilliant"*							
Autonomous SLAM	5 [1]	---	50 +	< 10	Autonomous IIR/MMW		F/A Aircraft
Terminal Guided Tomahawk	.4-.6	1,300 +	700 +	< 10	Autonomous IIR/MMW		F/A Aircraft

So-called Brilliant weapons are the next level or precision guidance that the USAF has taken a lead in. It consists of experiments with sensors and data processing in order to provide a complete closed-loop system for target ID and acquistion and lock-on.

Table 1. Representative Weapons Used in Force Projection

Major Soviet Equipment Delivered to the Third World

	Near East South Asia	Sub-Saharan Africa	Latin America	East Asia and Pacific	Totals
Tanks/ sp arty	5,750	985	840	350	7,925
Other Armor	11,075	1,625	750	650	14,100
Arty Mortars, MLRS	13,050	4,685	1,875	860	20,470
Combat A/C	2,315	530	225	450	3,520
Military Helos	1,150	310	155	90	1,705
Surface Ships	73	33	71	67	244
Subs	15	0	2	0	17
Missile Boats	16	9	6	6	37
SAMs	22,000	1,110	2,600	1,500	32,210

Source: DOD's Soviet Military Power 1989

Table 2. Select military exports by the U.S.S.R.

In SAMs alone, during this period, the Soviets exported nearly two times as many units to the Third World as the U.S. actually produced.

Operation EL DORADO CANYON
Attack Profile

Target	Planned A/C over Target	Planned bombing	Actual A/C over target	Actual bombing
Aziziyah Barracks	9 x F-111F 4 x 2,000 @	36 Mk 84 PVWY II LGB	3 x F-111F 1 x F-111f	13 hits missed 3 misses 4 aborts; 1 lost
Murat Sidi	3 x F-111F 4 x 2,000 @	12 Mk 84 PVWY II	3 x F-111F	12 hits
Tripoli AF	6 x F-111F 4 x 500 @	72 Mk 84 RDBs	5 x F-111F	60 hits 1 Abort
Jamahiriyah Barracks	7 x A-6E 4 x 500 @	84 Mk 82 RDBs	6 x A-6E 1 Abort	70 hits on deck 2 misses
Benina AF	8 x A-6E 12 x 500 @	72 Mk 20 CBUs 24 Mk 82 RBDs	6 x A-6E	60 hits 2 Aborts 12 misses 12 hits 12 misses
Tripoli AD Network	6 x A-7E 4 x SHRIKE/ HARM @	8 SHRIKE/ 16 HARMs	6 x A-7E	8 SHRIKEs 16 HARMs
Benghazi AD Network	6 x F/A-18 4 x SHRIKE/ HARM @	4 SHRIKE/ 20 HARMs	6 x F/A-18	8 SHRIKEs 16 HARMs
Totals	45 Aircraft 5 misses	300 Bombs 227 Hits	35 Bombed 48 STRIKE/ HARMs 1 attrited 48 missiles away	 1 missed

Source: <u>American's at War, p. 422</u>

Table 3. Operation EL DORADO CANYON Attack Profile.

Acceptable TLE

(Characteristic of Target Laser Designation [vice search] Mode)

Target Acquisition Range (ft)	NFOV Limit (Degrees/Plus or Minus) .5 °	1.0 °	1.5 °	1.5 °
1,000	87	175	262	350
2,000	175	349	524	698
3,000	262	524	785	1048
4,000	349	698	1047	1398
5,000	436	873	1309	1746
6,000	524	1047	1571	2094
7,000	611	1222	1832	2444
8,000	698	1396	2094	2792
9,000	785	1571	2356	3142
10,000	873	1745	2618	3490

Acceptable Target Location Error (TLE) in feet.

Source Texas Instruments Inc., Paveway Programs.

Table 4. Targeting POD NFOV vs. Acceptable TLE.

Prebriefed Weapon Environment for Autonomous Guidance Seeker Applications

(Fixed Targets)

Target Location Error	330
Navigational Error (ft)	1,000
Target Dimensional Acceptable(% error)	
(aspects of target folder product mensuration)	
Horizontal	.10
Vertical	.20
Azimuth Orientation	.05

Source Texas Instruments Inc., Advanced Interdiction Programs.

Table 5. Prebriefed Weapon Environment for Autonomous Guidance Seeker Applications.

GPS Navigation System Comparison

	Approximate		Approximate
System	Position Accuracy (ft)	Velocity Accuracy	
GPS	50 SEP (3-D)	.1 RMS (per axis)	Worldwide
LORAN-C	600 CEP	none	Selected
Omega	7,300 CEP	none	Worldwide
INS (Note 1.)	5,000 CEP	.8 RMS/2 hrs.	Internal
TACAN	1,300 CEP	none	Radio LOS

Note 1. SNU-84-1 Spec for USAF Std Form Fit and Function.

Source: Unpublished NWC Report on GPS.

Table 6. GPS Navigation System Comparison.

ANNEX III

EXPLANATION OF WEAPON LAUNCH CONDITIONS

Case	Launcher	weapon	target acquisition/ terminal lineup	guidance after weapon launch
1	aircraft	GP Bomb	MITL	none

The following is a simplified equation for probability of single shot kill (Pr_{ssk}) for Case 1.:

$$Pr_{ssk} = \underline{Pr_{d} * Pr_{i/d} * Pr_{a/i}\ Pr_{l/a}} * (1-Pr_{cl}) * Pr_{h} * Pr_{k/h}$$

Whereas:

Pr_{d}	=	Probability (P_r) that pilot detects desired target
$Pr_{i/d}$	=	P_r that pilot correctly identifies the desired target given detection
$Pr_{a/i}$	=	P_r that pilot acquires and lines up properly given correct target identification
$Pr_{l/a}$	=	P_r of launch given pilot acquires desired target
Pr_{cl}	=	P_r weapon system will inadvertently strike ground
Pr_{h}	=	P_r of weapon hit given no clobber
$Pr_{k/h}$	=	P_r of target kill given weapon hit

Whereas:

The underlined functions are those that involve Man-in-the-Loop (MITL) interface after aircraft launch. In Case one, the pilot (or aircrewman, i.e. Bombadier Navigator (B/N) ensures that before the weapon system is engaged, he uses a Line of Sight (LOS)-to-the-Target. This is the best guarantee that when using unguided ordnacne a target will be correctly identified and attacked. Launch failure is a function of weapon ballistic or aircrew lineup at launch errors only. Bomb damage assessment is possible if the aircrew maintains at least intermittent LOS to the target after launch.

Annex III-1. A simplified equation for probability of single shot kill.

Case	Launcher	weapon	target acquisition/ terminal lineup	guidance after weapon launch
2	aircraft	GP Bomb	Launch on Coordinates Radar/INS/GPS Cued	none

The following is a simplified equation for probability of single shot kill (Pr_{ssk}) for Case 2.:

$$Pr_{ssk} = \underline{Pr_{nav} * Pr_{l/nav}} * (1-Pr_{cl}) * \underline{\underline{Pr_{tgt} * Pr_{h/tgt} * Pr_{k/h}}}$$

Whereas:

Pr_{nav}	=	Probability (P_r) that pilot flies to within acceptible parameters launch: position, heading altitude and attitude,
$Pr_{l/nav}$	=	P_r of launch given pilot navigates correctly
Pr_{cl}	=	P_r weapon system will inadvertently strike ground
Pr_{tgt}	=	P_r that the target is within acceptable TLE for a given MAE
$Pr_{h/tgt}$	=	P_r of weapon hit given acceptable TLE and no clobber
$Pr_{k/h}$	=	P_r of target kill given weapon hit based on MAE

Whereas:

The underlined functions are those that involve post air-craft launch Man-in-the-Loop (MITL) interface. The double underlined functions are highly reliant on correct intelligence estimates and proper target input to the aircraft's computer in order to ensure acceptable Target Location Error (TLE) given the warhead's Mean Area of Effectiveness. (MAE) In Case two, the pilot (or aircrewman, i.e. Bombadier Navigator (B/N) must ensure before the weapon system engagment, he has arrived at a predetermined position or initial point (IP) WITHIN ACCEPTABLE LIMITS. Compared with Case 1. this condition is more reliant on good navigational planning and execution since there can be no guarantee a target is within the TLE other than intelligence estimates. In order to achieve a Bomb Damage Assessment (BDA) there must be a post strike reconnaissance mission with Satellite, RPV or manned a/c. (This is usually the case since the method is used to ensure aircraft survivability by preclusion of overflight of a defended target area.

III-2. A simplified equation for probability of single shot kill.

Case	Launcher	weapon	target acquisition/ terminal lineup	guidance after weapon launch
3	aircraft	PVWY II LGB	MITL/LOBL	command laser

The following is a simplified equation for probability of single shot kill (Pr_{ssk}) for Case 3.:

$$Pr_{ssk} = \underline{Pr_{d} * Pr_{i/d} * Pr_{a/i} * Pr_{l/a}} * (1-Pr_{cl}) * \underline{Pr_{wa/a}}$$

$$* Pr_{h/a} * Pr_{k/h}$$

Whereas:

Pr_{d} = Probability (P_r) that pilot detects desired target
$Pr_{i/d}$ = P_r that pilot correctly identifies the desired target given detection
$Pr_{a/i}$ = P_r that pilot acquires with targeting pod and lines up correctly given proper target identification
$Pr_{l/a}$ = P_r of launch given pilot properly acquires the target with the targeting pod
Pr_{cl} = P_r that weapon system will inadvertently strike ground
$Pr_{wa/a}$ = P_r of weapon acquistion of command aimed laser spot
$Pr_{h/a}$ = P_r of weapon hit given weapon guidance acquistion and no clobber
$Pr_{k/h}$ = P_r of target kill given weapon hit

Whereas:

The underlined functions are those that involve Man-in-the-Loop (MITL) interface after aircraft launch. All conditions in Case 3 are similar to Case 1 with the exception that terminal guidance if performed just prior (Lock-on-Before-Launch [LOBL] and maintained until weapon impact. $Pr_{w/a}$ is therefore highly dependent on the aircrew's ability to maintain LOS and designation until impact. Probability of BDA is similar to Case 1.

III-3. A simplified equation for probability of single shot kill.

Case	Launcher	weapon	target acquisition/ terminal lineup	guidance after weapon launch
4	aircraft	PVWY II/III LGB/LLLGB	MITL/LOAL Radar/INS/GPS Cued	command laser

The following is a simplified equation for probability of single shot kill (Pr_{ssk}) for Case 4.:

$$\underline{Pr_{ssk} = Pr_{nav}} * Pr_{1/nav} * (1-Pr_{cl}) * \underline{\underline{Pr_{d} * Pr_{i/d} * Pr_{lsr}}} *$$

$$Pr_{wa/lsr} * Pr_{h/wa} * Pr_{k/h}$$

Whereas:

- Pr_{nav} = Probability (P_r) that pilot flies to within acceptable parameters launch: position, heading altitude and attitude,
- $Pr_{1/nav}$ = P_r of launch given pilot navigates correctly
- Pr_{cl} = P_r weapon system will inadvertently strike ground
- Pr_{d} = P_r that pilot detects desired target after launch
- $Pr_{i/d}$ = P_r that pilot correctly identifies the desired target given detection
- Pr_{lsr} = P_r that the aircrew will properly acquire and lase the correct target at a second predetermined position, optimal for laser designation--LOAL--given correct target identification
- $Pr_{wa/lsr}$ = P_r of weapon acquisition of command aimed laser spot
- $Pr_{h/wa}$ = P_r of weapon hit given weapon acquisition and no clobber
- $Pr_{k/h}$ = P_r of target kill given weapon hit

Whereas:

The underlined functions are those that involve Man-in-the-Loop (MITL) interface after aircraft launch, but before target acquisition. The double underlined functions include MITL after weapon launch. All conditions in Case 4 are similar to Case 2 with the exception that terminal guidance if per-formed just after (Lock-on-After-Launch [LOAL]) and maintained until weapon impact. Pr_{d}, $Pr_{i/d}$ and Pr_{lsr} therefore are highly dependent on the aircrew reaching a second IP and good intelligence that the desired target is within an acceptable TLE (see table 5.) for Laser designation weapon ballistics. $Pr_{w/a}$ is highly dependent on the aircrew's ability to maintain LOS and designation until impact. Newer versions of the Paveway Laser Guided Bomb (LGB) with a 30 ° Field of View (FOV) afford fairly high $Pr_{w/a}$ when compared to older versions of the system.

III-4. A simplified equation for probability of single shot kill.

Case	Launcher	weapon	target acquisition/ terminal lineup	guidance after weapon launch
5	aircraft	GBU-15/AGM-130	MITL/LOAL Radar/INS/GPS Cued Launch on Coordinate	command TV

The following is a simplified equation for probability of single shot kill (Pr_{ssk}) for Case 5.:

$$Pr_{ssk} = \underline{Pr_{nav} * Pr_{l/nav}} * (1-Pr_{cl}) * \underline{\underline{Pr_{d} * Pr_{i/d} * Pr_{wa/i}}} *$$

$$\underline{\underline{Pr_{cg/wa} * Pr_{h/cg} * Pr_{k/h}}}$$

Whereas:

Pr_{nav}	=	Probability (P_r) that pilot flies to within acceptable parameters launch: position, heading altitude and attitude,
$Pr_{l/nav}$	=	P_r of launch given pilot navigates correctly
Pr_{cl}	=	P_r weapon system will inadvertently strike ground
Pr_{d}	=	P_r that pilot/WSO detects desired target through the weapon seeker after launch
$Pr_{i/d}$	=	P_r that pilot/WSO correctly identifies the desired target given detection
$Pr_{wa/i}$	=	P_r that the weapon will properly acquire correct target given proper identification--*LOAL*
$Pr_{cg/wa}$	=	P_r of command guidance given proper acquisition
$Pr_{h/wa}$	=	P_r of weapon hit given command guidance
$Pr_{k/h}$	=	P_r of target kill given weapon hit

The underlined functions are those that involve Man-in-the-Loop (MITL) interface after aircraft launch, but before target acquisition. The double underlined fuctions unclude MITL after weapon launch.

III-5. A simplified equation for probability of single shot kill.

Case	Launcher	weapon	target acquisition/ terminal lineup	guidance after weapon launch
6	aircraft	GBU-15/ AGM-130 SLAM/PVWY III +	Weapon System LOAL Launch on Coordinates Radar/INS/GPS Cued	Autonomous IIR, mmw

The following is a simplified equation for probability of single shot kill (Pr_{ssk}) for Case 6.:

```
Prssk = Pr nav * Pr 1/nav * (1-Pr cl) * Pr wd * Pr wi/wd *
        ----------------   ============================

        Pr wa/wi * Pr wg/wa  * Pr h/wg * Pr k/h
        ==============================
```

$$Pr_{ssk} = Pr_{nav} * Pr_{1/nav} * (1-Pr_{cl}) * Pr_{wd} * Pr_{wi/wd} * Pr_{wa/wi} * Pr_{wg/wa} * Pr_{h/wg} * Pr_{k/h}$$

Whereas:

Pr_{nav}	=	Probability (P_r) that pilot flies to within acceptable parameters launch: position, heading altitude and attitude,
$Pr_{1/nav}$	=	P_r of launch given pilot navigates correctly
Pr_{cl}	=	P_r weapon system will inadvertently strike ground
Pr_{wd}	=	P_r that weapon onboard system detects desired target with own seeker after launch
$Pr_{wi/d}$	=	P_r that weapon on board system correctly identifies the desired target given weapon system detection of target
$Pr_{wa/wi}$	=	P_r that the weapon will properly acquire correct target given proper identification--LOAL
$Pr_{wg/wa}$	=	P_r of weapon automatic guidance given proper weapon sytem acquisition
$Pr_{h/wg}$	=	P_r of weapon hit given weapon automatic guidance
$Pr_{k/h}$	=	P_r of target kill given weapon hit

The underlined functions are those that involve Man-in-the-Loop (MITL) interface after aircraft launch, but before target acquistion. The double underlined fuctions unclude MITL after weapon launch. In order to operate in this mode, a weapon systems pre-flight mission briefing must include relative and absolute target area locations and dimensions. Table 5 is an example of predicted values for target intelligence error tolerance or target location errors broken into components (TLE).

III-6. A simplified equation for probability of single shot kill.

Case	Launcher	weapon	target acquisition/ terminal lineup	guidance after weapon launch
7	aircraft	Standoff Land Attack Missile (SALM)	MITL/LOAL Radar/INS/GPS Cued Launch on Coordinates	Command TV

The following is a simplified equation for probability of single shot kill (Pr_{ssk}) for Case 7.:

$$Pr_{ssk} = \underline{Pr_{nav} * Pr_{l/nav}} * (1-Pr_{cl}) * \underline{\underline{Pr_{d} * Pr_{i/d} * Pr_{wa/i}}} *$$

$$\underline{\underline{Pr_{cg/wa} * Pr_{h/cg} * Pr_{k/h}}}$$

Whereas:

Pr_{nav} = Probability (P_r) that pilot flies to within acceptable parameters launch: position, heading altitude and attitude,

$Pr_{l/nav}$ = P_r of launch given pilot navigates correctly

Pr_{cl} = P_r weapon system will inadvertently strike ground

Pr_{d} = P_r that pilot/BN detects desired target through the weapon seeker after launch

$Pr_{i/d}$ = P_r that pilot/BN correctly identifies the desired target given detection

$Pr_{wa/i}$ = P_r that the weapon will properly acquire correct target given proper identification--LOAL

$Pr_{cg/wa}$ = P_r of command guidance given proper acquisition

$Pr_{h/wa}$ = P_r of weapon hit given command guidance

$Pr_{k/h}$ = P_r of target kill given weapon hit

The underlined functions are those that involve Man-in-the-Loop (MITL) interface after aircraft launch, but before target acquisition. The double underlined fuctions unclude MITL after weapon launch. The major difference between Cases 5 and 7 is that with Standoff Land Attack Missile (SLAM) terminal standoff range is increased (Table 1.) and launch "basket" parameters (altitude, course etc.) are relaxed in that a missile with GPS midcourse guidance (Table 6.) can compensate for more launch error than a glide bomb or boosted glide bomb. This of course is critical in a high threat environment (i.e. due to jinking requirements and subsequent navigation error/ adjustments and compensation.)

III-7. A simplified equation for probability of single shot kill.

Case	Launcher	weapon	target acquisition/ terminal lineup	guidance after weapon launch
8	Sub Surface Ship	TLAM-C	Launch to Coordinates Positional NAV only	Autonomous TERCOM

The following is a simplified equation for probability of single shot kill (Pr_{ssk}) for Case 8.:

$$Pr_{ssk} = \underline{Pr_{l}} * \underline{\underline{Pr_{nav} * (1-Pr_{cl}) * Pr_{tgt} * Pr_{h/tgt} * Pr_{k/h}}}$$

Whereas:

Pr_{l} = Probability (P_r) of launch given tactical commander is satisfied with APS pre-launch mission planning

Pr_{nav} = P_r that TLAM flies to within acceptable positional limits for Pr_{tgt}

Pr_{cl} = P_r weapon system will inadvertently strike ground

Pr_{tgt} = P_r that the target is within acceptable TLE for a given MAE

$Pr_{h/tgt}$ = P_r of weapon hit given acceptable TLE and no clobber

$Pr_{k/h}$ = P_r of target kill given weapon hit based on MAE

Whereas:

The underlined functions are those that involve pre TLAM launch with Man-in-the-Loop (MITL) interface. The double underlined functions are totally dependant on pre launch input and are highly reliant on correct intelligence estimates and proper target input to TLAM's on board system in order to ensure acceptable Target Location Error (TLE) given the war-head's Mean Area of Effectiveness. (MAE) Essentially an unmanned aircraft, system algorithms perform similar functions of a pilot or Bombadier Navigator (B/N) in Case 2. Compared with manned fligth options, this condition is totally reliant on pre-flight navigational planning since there can be no guarantee a target is within the TLE other than intelligence estimates. In order to achieve a Bomb Damage Assessment (BDA) there must be a post strike reconnaissance mission with Satellite, RPV or manned a/c.

III-8. A simplified equation for probability of single shot kill.

Case	Launcher	weapon	target acquisition/ terminal lineup	guidance after weapon launch
9	Aub	TLAM-C+	Weapon System LOAL	Autonomous IIR, mmw

The following is a simplified equation for probability of single shot kill (Pr_{ssk}) for Case 9:

$$Pr_{ssk} = \underline{Pr_{1}} * \underline{\underline{Pr_{nav} * (1-Pr_{cl}) * Pr_{wd/nav} * Pr_{wi/wd}}} *$$

$$\underline{\underline{Pr_{wa/wi} * Pr_{wg/wa} * Pr_{h/wg} * Pr_{k/h}}}$$

Whereas:

Pr_{1}	=	Probability (P_r) of launch given tactical commander is satisfied with APS prelaunch mission prebriefing
Pr_{nav}	=	P_r that TLAM flies to within acceptable parameters to initiate target seeker search
Pr_{cl}	=	P_r weapon system will inadvertently strike ground
$Pr_{wd/nav}$	=	P_r that weapon onboard system detects desired target with own seeker after launch given acceptable navigation solution is met
$Pr_{wi/wd}$	=	P_r that weapon on board system correctly identifies the desired target given
$Pr_{wa/wi}$	=	P_r that the weapon will properly acquire correct target given proper identification--LOAL
$Pr_{wg/wa}$	=	P_r of weapon automatic guidance given proper weapon sytem acquisition
$Pr_{h/wg}$	=	P_r of weapon hit given weapon automatic guidance
$Pr_{k/h}$	=	P_r of target kill given weapon hit

Whereas:

The underlined functions are those that involve pre TLAM launch with Man-in-the-Loop (MITL) interface. The double underlined functions are totally dependant on pre launch input and are highly reliant on correct intelligence estim-ates and proper target input to TLAM's on board system. Case 9 combines the functions of Cases 6 and 8. In so doing it combines the capability for a cruise missile to preclude the need of any manned aircraft penetration, with the system reliability that terminal guidance to an acquired target structure (target acquisition vs. positional only). (See Tables 5 and 6.)

III-9. A simplified equation for probability of single shot kill.

ANNEX IV

TECHNICAL DATA OF SELECTED WEAPONS AND SYSTEMS

TOMAHAWK is a long-range cruise missile for both surface and submarine launch against land targets. Initially known as the Sea-Launched Cruise Missile (SLCM), various versions of TOMAHAWK includes anti-ship (TASM), land attack with a conventional warhead (TLAM-C), and land-attack with a nuclear warhead (TLAM-N). All versions operate at very low altitudes and have a radar cross-section of approx 10.76 sq ft (1 sq m). The missile is sealed in its launch canister at the factory and can be treated as a "wooden round."

Both TLAM versions have an inertial guidance phase, after which the missile's accuracy is updated using Terrain-Contour Matching (TERCOM). TERCOM measures actual land contours with its on-board radar altimeter and compares them to stored digitized profiles. The profile's land area decreases as the missile nears its target. While TLAM-N uses inertial and TERCOM guidance alone, TLAM-C uses Digital Scene-Mapping Area Correlator (DSMAC) as it nears the target for still greater accuracy. DSMAC correlates the optical view of the target area with digitized target maps, fine-tuning the missile's terminal flight. Target map up-dating involves relatively simple DSMAC reprogramming. Either version can fly preprogrammed evasive flight paths between guidance updates.

Navy's procurement goals are reported as approximately
600 TASM
760 TLAM(N)
1,490 TLAM(C) with unitary warhead
1,160 TLAM(C) with submunition warhead (BGM-109D)

PLATFORMS	CLASS	LAUNCHER
submarines	STURGEON (SSN 637)	torpedo tubes
	NARWHAL (SSN 671)	torpedo tubes
	LOS ANGELES (SSN 688-718)	torpedo tubes
	LOS ANGELES (SSN 719 and later ships)	12 vertical launch tubes
	SEAWOLF (SSN-21) (planned)	torpedo tubes
battleships	IOWA (BB 61)	4 Mk 143 ABL
cruisers	VIRGINIA (CGN 38)	2 Mk 143 ABL
	LONG BEACH (CGN 9)	2 Mk 143 ABL
	TICONDEROGA (CG 47) (beginning with CG 52)	2 Mk 41 VLS
destroyers	SPRUANCE (DD 963)	1 Mk 41 VLS (24 of class being refitted)
	SPRUANCE (DD 963)	2 Mk 143 ABL (7 ships)
	ARLEIGH BURKE (DDG 51) (planned)	1 Mk 41 Mod 2VLS

Performance

speed	Mach 0.7
maximum range	
TASM	more than 250 nm
TLAM-C	approx 700 nm
TLAM-N	approx 1,350 nm

Warhead: conventional high-explosive in TASM
nuclear 5 to 150-kiloton W80 in TLAM-N

Accuracy
Circular Error Probable (CEP)
less than 0.02 nm (30.5 m)

Guidance
Ships with Mk 143 AEL have AN/SWG-2 weapon control system
Ships with Mk 41 VLS have AN/SWG-3 weapon control system
Submarines have Mk 117 fire control system

TASM inertial; terminal is active radar homing (similar to Harpoon)

TALM-C inertial; terminal is Terrain Contour Matching (TERCOM) with Digital Scene-Mapping Area Correlator (DSMAC)

TLAM-N inertial and TERCOM

VARIANTS

BGM-109A	TLAM	W80 nuclear warhead, 5-150 kiloton
BGM-109B	TASM	conventional 1,000-lb (907-kg) WDU-25B warhead from discarded Bullpup missiles
BGM-109C	TLAM	warhead same as BGM-109B
BGM-109D	TLAM	166 Aerojet General BLU-97/B "bomblets"; each bomblet weighs 3.4 lb (1.5 kg); first tested November 1987
BGM-109E	TASM	magnesium reactive warhead
BGM-109F	TLAM	airfield attack submunitions

PROGRAM ACQUISITION COSTS (IN MILLIONS)
(January 1990 Proposal for FY1991 Budget)

	Actual FY1989	Actual FY1990	Proposed FY1991
Procurement	510	400	600

UNIT COST (FY1991) $1,347,888
Source US Naval Institute on-line data base.

AGM 84E/SLAM
The Standoff Land Attack Missile (SLAM) is a derivative of the HARPOON anti-ship missile designed to engage ships and land targets. SLAM is to be launched from carrier-based aircraft. It shares common control, warhead, and sustainer sections with HARPOON, but it also has a PS that allows the missile's path to be updated or corrected after launch. In addition to using HARPOON components, SLAM adopts the Imaging Infrared (IIR) seeker of the AGM-65 Maverick and the data link of the AGM-62 Walleye.

When the seeker is activated, the pilot/weapons officer receives a video image of the target and can select an aiming point on the target for a precision strike. The missile then operates autonomously. The missile can also be con-trolled from a plane other than the firing plane. In tests, the SLAM was launched from an A-6E and locked on to target by an accompanying A-7E pilot.

STATUS Initial Operating Capability (IOC) planned for 1990. The 1988 Department of Defense master plan for standoff weapons included limited pro-curement approval for the SLAM. Funding had been eliminated in FY1990 and the Navy was interested in an initial buy of 360 units. (It is hard to determine at this time where SLAM procurement is heading given its early successes in OPERATION DESERT STORM.)

USERS/PLATFORMS
USA
Navy (planned)

attack	A-6E Intruder
fighters	F/A-18 Hornet

speed .85 Mach

range	50+ nm (58+ mi; 93+ km)
Warhead	blast/fragmentation high explosive

Sensors/Fire Control

on-board midcourse guidance unit
Global Positioning System (GPS) receiver

Lear-Siegler or Northrop 3-axis attitude reference assembly
AN/APN-194 short-pulse radar altimeter
terminal homing through AGM-65D Maverick IIR seeker and the AGM-62 Walleye data link

Source USNI Online Data Base.

AGM-130 is a powered version of the US GBU-15 precision-guided modular glide bomb, which in turn evolved from the Mk 84 2,000 lb. Commonality between the two weapons includes the TV seeker, body, and short-chord wings. Warheads for the GBU-15 are the Mk 84, a submunitions dispenser (SUU-54), or the more pow-erful BLU-109 unitary warhead. (The SUU-54 warhead is not planned for the AGM-130.)

In addition to its rocket motor, the AGM-130 differs from the GBU-15 in the provision of a digital autopilot and radar altimeter. The rocket motor ex-tends the range of the AGM-130 up to 3 times farther than the GBU-15 under similar launch conditions.

The AGM-130 can be launched from low altitudes against high value fixed targets. Its flight profile consists of a glide phase, a powered phase (after which the rocket separates from the missile), and a final glide phase. Mid-course corrections are passed through a jam-resistant data link (under development) that is an improvement over the GBU-15's AXQ-14. Targeting op-tions can be Lock-On Before Launch (LOBL) or After Launch (LOAL), which pro-vides for automatic tracking, or through joystick control by the weapon system operator on board the launch aircraft. The weapons systems officer can also update a locked-on AGM-130 during the flight.

In an October 1989 test, an AGM-130 was released from an F-4E at 350 ft, it climbed to 1,000 feet before being guided to a direct hit on target.

STATUS Initial operational capability of GBU-15 (TV) in 1983, GBU-15 (IIR) in 1987. Procurement of the AGM-130 was cancelled for FY1989, but funding was reinstated for FY1991. The Air Force conducted 9 initial operational test and evaluation launches, be-ginning in June 1989. 8 of the 9 launches were suc-cessful with 6 direct hits.

PLATFORMS

Attack	F-4E	Phantom
	F-15E	Eagle
	F-111F	
Bombers	B-52G	Stratofortress

CHARACTERISTICS

Performance	
range	
maximum	
GBU-15	4.3 nm
AGM-130	26 nm
Warhead	Mk-84 conventional high explosive or explosive submunitions

Sensors/Fire Control
guidance manual command through 2-way data link or automatic TV or IIR guidance through pre- or post-launch lock-on

VARIANTS As noted above, 3 warhead and 2 seeker variants are in service or under development.

ISSUES Software problems (particularly in the digital auto-pilot) and test flight failures (incorrect timing of the rocket's separation from the missile) have delayed the AGM-130 and increased costs.

On 17 December 1987 the entire flight profile of the AGM-130 had its first successful test after having been launched from an Air Force F-4E Phantom. This was not enough to overcome earlier developmental problems, and due to a shrinking defense budget, funding for the program was cut. The Air Force continued development tests and test launches from the F-111 and F-4E began in 1989.

OPERATIONAL NOTES The GBU-15 is based on the original Pave Strike GBU-8 used to great effect in the latter part of the Vietnam War.

PROGRAM ACQUISITION COSTS (IN MILLIONS)
(January 1990 Proposal for FY1991 Budget)

	Actual FY1989	Actual FY1990	Proposed FY1991
AGM-130 Procurement	----	(28) 35.0	(63) 38.4
GBU-15 Procurement	----	1.3	28.4

AGM-130 Unit Cost (FY 1991) $610,063

AGM-62 WALLEYE The US air-to-ground Walleye glide bomb was one of the first "smart bombs" to enter US service. It was developed to take advantage of then-new TV guidance technology that would yield the accuracy of a guided weapon without requiring the launch aircraft to fly toward the target until the bomb's impact.

The Walleye has no propulsion, gliding instead in on its target on cruciform wings. The nose TV camera can be locked onto a high-contrast spot on a target before launch by the launch aircraft's pilot or weapons officer. The operator focuses the camera on the target, locks that image in the camera, and launches the bomb. Once the weapon is released, it is self-homing as the camera retains its lock on the target spot until impact. If necessary, the pilot can provide update com-mands through a radio link in mid-flight. In combat use, the updates were often provided by another aircraft several miles away, which reduced the vulner-ability of the launch aircraft.

STATUS Initial operational capability in 1967.

4,531 Walleye I and 951 Walleye II were built.

USERS Israel

CHARACTERISTICS

Performance	
speed	subsonic
range	
maximum	
Walleye I	16 nm (18.4 mi; 29.6 km)
Walleye II	35 nm (40.3 nm; 64.9 km)
Warhead	linear shaped-charge
Accuracy	
Circular Error Probable (CEP) in peacetime	15 ft (4.6 m)
Sensors/Fire Control	
guidance	TV homing with update through data link

VARIANTS Walleye II Also known as "Fat Albert" after a character created by comedian Bill Cosby. Larger wings, heavier warhead, and a TV seeker with a smaller lock-on "gate" for greater accuracy. Over 2,400 Walleye II completed, 1,481 of which were converted from Walleye I; 951 additional weapons built in mid-1970s.

Extended-Range/Data-Link (ER/DL) Walleye Range extended by including Lock-On After Launch (LOAL) capability. Weapon could be dropped before target was selected, further reducing launch aircraft vulnerability. 2-way radio data link allows weapons officer to delay lock-on until the Walleye nears the target. Lock-on can be commanded by second aircraft. 1,400 Walleye I and 2,400 Walleye II converted to ER/DL configuration.

ISSUES Although the Walleye could be quite accurate and had an impressive specified stand-off range, the early version possessed 2 significant limitations. One was the 15 seconds it typically took to get the bomb's TV camera to lock-on; a 1968 Defense Department report noted that the average slant range to target by the time lock-on was accomplished was only 1.5 nm. As a result, the attacking aircraft was hit by anti- aircraft fire 4 times as often as the pilot who dropped conventional bombs.

The other limitation lay in the small warhead, which was not powerful enough to damage large buildings and steel or concrete bridges. The large buildings required too many weapons and the low contrast offered by bridge targets often seduced the TV seeker into locking onto main support girders that resisted the warhead's effects.

OPERATIONAL NOTES US Air Force and Navy aircraft used Walleyes against North Vietnamese targets in the late 1960s and early 1970s. 78% of Walleyes launched by naval aircraft reportedly hit; 49% of Air Force Walleye deliveries were considered successful.

GLOBAL POSITIONING SYSTEM (GPS).

GPS is a space-based radio positioning, navigation and time transfer system consisting of 18 satellites. The satellites operate in high earth orbits which are relatively safe from intercept. They are spaced such that at any given time at least four satellites will be visibel at any location on the earth's surface. Satellite radio signals will passsively provide users with position, velocity, and time while correcting for atmospheric propagation. Aircraft such as the F-16C and F-18C will determine global position with 15 meters (or less) three-dimensional accuracy and velocity to .1 meters per sec-ond, respectively. Aside from its precise navigation positioning, such accur-acy will will allow:

* Precise bombing with launch on coordinates tactics;
* Inertial Navigation Updates;
* Backup steering in the event of INU failure;

Without GPS updates, typical launch on coordinates using INS updates only and the F-16C provide accuracies on the order of 600 feet. With GPS accuracies will be much greater.

Source: USAF Fighter Weapons Review, Spring 1985.

Although listing specific bombing accuracies are beyond the classification level of this report, consider the following:

Derive from the given variables:

Total target area = The Square Root of (CEP squared + TLE Squared)

Whereas CEP equals ballistic error and original INS or GPS NAV error:

CEP $_{INS}$ = Total error^2 (600)^2 (given)
- Ballistic error^2 (358)^2 (see Figure 3.)
- INS NAV error^2 (481)^2 (computed)

Derived INS NAV error = 481
==========================

GPS Error = 50 (given, Table 3) @ 12 mil ballistic error

CEP $_{GPS}$ = Total error^2 (361)^2 (computed)
- Ballistic error^2 (358)^2 (see Figure 3.)
- GPS NAV error^2 (50)^2 (given)

Derived CEP $_{GPS}$ @ 12 mil Ballistic error = 361
==

GPS Error = 50 (given, Table 3) @ 6 mil ballistic error

CEP_{GPS} = Total error^2 (186)^2 (computed)
- Ballistic error^2 (180)^2 (see Figure 3.)
- GPS NAV error^2 (50)^2 (given)

Derived CEP_{GPS} @ 6 mil Ballistic error = 186

GPS Error = 50 (given, Table 3) @ 3 mil ballistic error

CEP_{GPS} = Total error^2 (102)^2 (computed)
- Ballistic error^2 (90)^2 (see Figure 3.)
- GPS NAV error^2 (50)^2 (given)

Derived CEP_{GPS} @ 3 mil Ballistic error = 102

A 3 mil ballistic error GPS can provide launch on coordinate accuracies typical of GP bombs and MITL/LOS to target cue.

Author's Derivation

BACKNOTES

[1] Thomas A. Brooks, RADM USN, Statement of Rear Admiral Thomas A. Brooks, U.S. Navy, Director of Intelligence, Before the Seapower, Strategic and Critical Materials Subcommittee of the House Armed Service Committee on Intelligence Issues., 14 March 1990. P. 1

[2] Ibid.

[3] Barry M. Blechman and Stephen S. Kaplan, The Use of the Armed Forces as a Political Instrument. WAshington: The Brookings Institute. 1977, p. 3.

[4] ADM J.D. Watkins (former CNO), "The Maritime Strategy", The Maritime Strategy, Annapolis MD: USNI Press, August 1986. pp. 6-7.

[5] CDR Robert M. Nutwell, USN "Deep Six for Tac Air?", U.S. Naval Institute Proceedings. January 1983., p.79.

[6] Col. Stanley P. Dereska, USAF (ret.) "Quick Technical Applications Field Adanced Capabilities", Signal. Nov. 1990, p. 19.

[7] James W. Canan, Senior Editor, "Comeback of the AGM-130", AIR FORCE Magazine. April 1990, p. 55.

[8] Ibid. p. 55-56.

[9] David Brown, Christpher Shores and Kenneth Macksey, The Guinness History of Air Warfare. Enfield, Middlesex UK: Guiness Superlatives LTD. 1976, p. 149.

[10] Lon O. Nordeen, Jr., Air Warfare in the Missile Age. Washington, D.C.: Smithsonian Institute Press 1985, p. 59.

[11] Nordeen, p. 59.

[12] Brown, et al. p. 216.

[13] VADM Joseph Metcalf III, USN (ret.) "Decision Making and the Grenada Rescue Operation", Ambiguity and Command Organizational Perspectives on Military Decision Making. James G. March and Roger Weissinger-Baylon eds. New York: Harper Collins Publishers 1986, pp. 281-2.

[14] Martin Van Crevald, Command in War. Cambridge, MA.: Harvard University Press, 1985, p. 1-2.

[15] GEN Larry D. Welch, USAF, quoted by James W. Canan, "To Command You Must Have Control", Air Force. Assocation of the Air Force, July 1990. p. 41.

BACKNOTES (cont'd)

[16] Nordeen, p. 59.

[17] Brown, et al. p. 216

[18] Daniel P. Bolger, Americans at War. Novasto, CA., Presidio Press: 1988, p. 387.

[19] Ibid. p. 388.

[20] Ibid. p. 410.

[21] Ibid. p. 429-30.

[22] Ibid. p. 430.

[23] Ibid.

[24] Congressman Denny Smith "Restock Inadequate Munitions Reserves", Wall Street Journal., 29 October, 1985. p. 28.

[25] RADM Henry E. Eccles, "Command and Control: The Logistics Base", Naval Research Logistics Qaurterly. Washington D.C.: 2 June 1962. p. 97.

[26] Ashton B. Carter, John D. Steinbruner and Charles A Zraket Ed. Managing Nuclear Options. Washington D.C.: Brookings Institute, 1987 p. 281

[27] CDR Robert M. Nutwell, p. 78.

[28] LCDR Richard J. Pera, USN "Focus on the Future: Naval Intelligence in the Post-Cold War Era." Naval War College unpublished report N 420 f95 1990. p. 9.

[29] Craig Covault, "Space Recon of Iraq Taxes CIA Operations", Aviation Week and Space Technology. 3 Sep 1990, p. 30.

[30] David C. Hazen, "Nine Prejudices about Future Naval Systems" U.S. Naval Institute Proceedings. Jul 1980, p. 31.

[31] Pera p. 8.

[32] Ibid. p. 8.

[33] Glenn W. Goodman, Jr., "Services Groom a New Generation of Tactical Missiles" Armed Forces Journal International. Nov 1990, p. 44.

[34] James W. Canan. p. 55

BACKNOTES (cont'd)

[35] Glenn W. Goodman, Jr. p. 45.

[36] LCDR Richard J. Pera, p. 9.

[37] Craig Covault. p. 30.

[37] Ibid.

[38] LCDR Richard J. Pera, USN, p. 13.

BIBLIOGRAPHY

Blechman Barry M. and Stephen S. Kaplan, The Use of the Armed Forces as a Political Instrument. WAshington: The Brookings Institute. 1977.

Bolger, Daniel P., Americans at War. Novasto, CA., Presidio Press: 1988.

Brooks, Thomas A. Brooks. Statement of Rear Admiral Thomas A. Brooks, U.S. Navy, Director of Intelligence, Before the Seapower, Strategic and Critical Materials Subcommittee of the House Armed Service Committee on Intelligence Issues., 14 March 1990.

Brown, David, Shores Christopher and Macksey Kenneth, The Guiness History of Air Warfare. Enfield, Middlesex UK: Guiness Superlatives LTD., 1976.

Canan, James W. , "Comeback of the AGM-130", Air Force Magazine. Association of the Air Force, April 1990.

Canan, James W., "To Command You Must Have Control", Air Force. Association of the Air Force, July 1990.

Carter, Ashton B. Steinbrunner, John D. Steinbruner Zracket, Charles A Zraket Ed. Managing Nuclear Options. Washington D.C.: Brookings Institute, 1987.

Covault, Craig, "Space Recon of Iraq Taxes CIA Operations", Aviation Week and Space Technology. 3 Sep 1990.

Dereska, Stanley P. "Quick Technical Applications Field Adanced Capabilities", Signal. Nov. 1990.

Ecles, Henry E., "Command and Control: The Logistics Base", Naval Research Logistics Qaurterly. Washington D.C.: 2 June 1962.

Goodman, Glenn W. Jr., "Services Groom a New Generation of Tactical Missiles" Armed Forces Journal International. Nov 1990.

Hazen, David C. Hazen, "Nine Prejudices about Future Naval Systems" U.S. Naval Institute Proceedings. Jul 1980.

Metcalf, Joseph Metcalf III, "Decision Making and the Grenada Rescue Operation", Ambiguity and Command Organizational Perspectives on Military Decision Making. James G. March and Roger WeissingerBaylon eds. New York: Harper Collins Publishers, 1986.

Nordeen, Lon O. Jr., Air Warfare in the Missile Age. Washington, D.C.: Smithsonian Institute Press 1985.

Nutwell, Robert M. "Deep Six for Tac Air?", U.S. Naval Institute Proceedings. January 1983.

Pera, Richard J. "Focus on the Future: Naval Intelligence in the Post-Cold War Era." Naval War College unpub-lished report N 420 f95, 1990.

Smith, Denny, "Restock Inadequate Munitions Reserves", Wall Street Journal., 29 October, 1985.

Vav Crevald, Martin, Command in War. Cambridge, MA.: Harvard University Press, 1985.

Watkins J.D. , "The Maritime Strategy", The Maritime Strategy, Annapolis MD: USNI Press, August 1986.